OBSERVATIONS ON THE DIATOM FLORA FROM SPRINGS ALONG THE BALCONES FAULT, TEXAS

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This is a single summer study of the diatoms from selected large Texas springs. To the author's knowledge this is the only investigation specific to diatoms from these areas. These are in all cases rapid flowing springs producing large volumes of water.

The literature indicates that few studies have been completed on diatoms from spring habitats. In the United States, Whitford (1956) and Hohn (1961) have studies on diatoms from Florida springs and Reimer (1961) discusses spring diatoms in his work from Indiana. Cholonoky (1933-34) and Hustedt (1945) have produced reports on diatoms from springs in Europe. Other works from Europe include Foged's (1951) studies on diatoms in Danish springs and the two papers by Round (1957, 1960) on diatom flora in English springs (Table 5). These works in a general way seem to indicate that there is not a true "spring-type" diatom flora but rather these flora are more similar to small stream flora than river or lake assemblages.

Study Areas

The study areas include three spring complexes along the Balcones Fault which runs through central Texas (Map 1). Indications are that the water for all three collecting areas is furnished by the Edwards Underground Reservoir (Map 2).

The Balcones zone of faulting was formed under conditions of strain during Tertiary times by the down-warping near the Gulf Coast and moderate uplift inland (Sellards, et al 1932). The area is made up of natural and/or gravity faults with the major down throw being to the east. This area is at the edge of the Edwards plateau having rock formations constructed mainly of limestone with some amount of out-cropping.

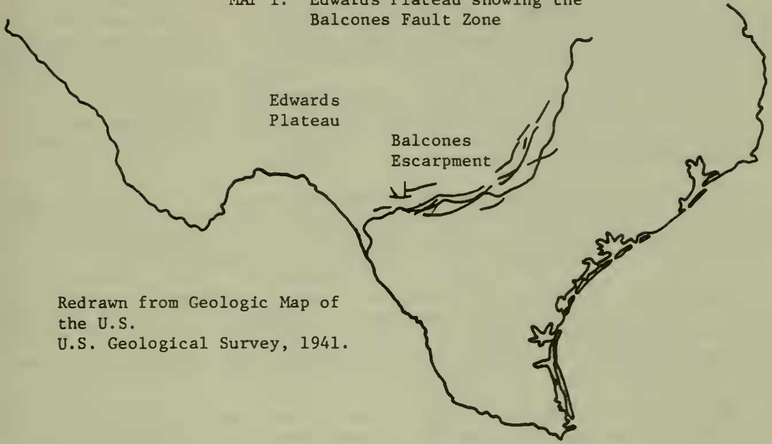
The springs considered in this study are of the artesian type known as "fissure springs" as opposed to gravity springs also found in the area. These springs are associated with the Balcones scarp line and associated faults. They are the most prominent of a chain of springs extending in a continuous line for 250 miles between Austin and Del Rio, Texas (Map 2). They appear at the foot of the Balcones escarpment from openings in the Cretaceous limestone. The faults of the Balcones escarpment run southwest for 80 miles from Austin to San Antonio and, from there, west for 150 miles to Del Rio (Map 2).

The water reservoir feeding these springs is the Edwards (Balcones Fault Zone) Aquifer, not to be confused with the more extensive and deeper Edwards-Trinity (Plateau) Aquifer which lies to the west. The location and size of the aquifer in this study can be observed on Map 2.

The aquifer is not at great depth and is, in part, recharged by spring-fed streams as they flow across the Balcones fault zones. Because of this, spring

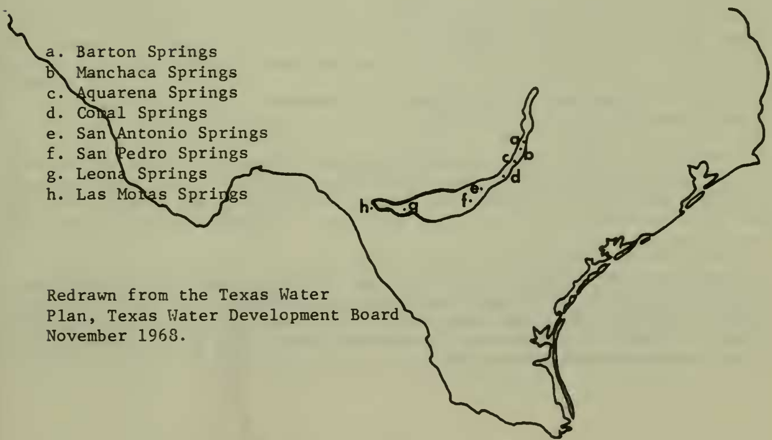
SOUTH-CENTRAL TEXAS

MAP 1. Edwards Plateau showing the Balcones Fault Zone



Redrawn from Geologic Map of the U.S.
U.S. Geological Survey, 1941.

MAP 2. Edwards Aquifer with Spring Locations



Redrawn from the Texas Water Plan, Texas Water Development Board November 1968.

flow, mineral content and temperature are affected, with but a short lag, by environmental conditions of the area.

Average winter temperature in the area is about 51.2°F. Summer temperatures average 84.2°F. Thus average yearly temperature in the Balcones fault area is about 68°F. As can be seen in Table 2, this is in close agreement with the observed water temperatures of 21+°C (69.8°F) found in the springs considered.

Annual precipitation in the area ranges from 33.24 inches in the east to 25.91 inches in the west. The rainfall, of course, varies from year to year and this, in turn, affects the depth of the water below the land surface and the rate of flow of the springs.

Normal depth of the Edwards Aquifer is 40-50 feet below the surface. The water level dropped to 100 feet and below during the drought of the early 1950's in central Texas. Many of the major springs have never recovered from the drought and have flow limited only to abnormally high water periods.

Study sites include spring complexes in Austin, San Marcos and New Braunfels. In each of these areas there are many points of upwelling underground water from cracks between the rocks (Table 1). Because of the force and volume of water, these springs must be classified as true rheocrenes. The resulting water may form various sized pools or develop directly in streams.

The study site at Barton Springs in Austin was a rather large body of slow moving water. The collection area at Aquarena Springs was a man-made impoundment with almost no water flow in the spring area. The study area at Comal Springs in New Braunfels was represented by a small but rapid flowing stream formed by the upwelling spring water.

Sampling Stations

The first collecting site included a number of springs located in southwest Austin (Latitude 30°16' north and Longitude 97°47' west). These springs are known locally as Barton or Zilker Springs. They are located in and near Barton Creek where it flows through Zilker Park. The area containing the major spring complex has been dammed and treated with chlorine to produce a public swimming pool. Most of the minor spring areas are contained in man-made rock structures so as to create an unnatural habitat.

The second study area, known as Aquarena Springs, is located in the city of San Marcos (Latitude 29°53' north and Longitude 97°51' west) about thirty miles south of the first collecting site. These springs are located in a park area in the north part of the city. Man-made containing walls are present in most of the spring area.

The final collecting site was springs in Landa Park in the city of New Braunfels (Latitude 29°43' north and Longitude 98°07' west) about fifty miles south of the first collecting area. It proved to be the least disturbed, most natural of the collecting sites. These are called Comal Springs and are considered to be the largest in Texas.

TABLE 1. Springs related to the Balcones fault belt of Texas and their flow rates.

NAME	LOCATION	SPRING FLOW	
Barton Springs	Austin	40 sec.-ft.	26,000,000 gal./day
Manchaca Springs	Buda	---	---
Aquarena Springs	San Marcos	135 sec.-ft.	100,000,000 gal./day
Comal Springs	New Braunfels	350 sec.-ft.	220,000,000 gal./day
San Pedro Springs	San Antonio	---	---
San Antonio Springs	San Antonio	90 sec.-ft.	---
Leona Springs	Uvalde	---	---
Las Moras Springs	Brackettville	34 sec.-ft.	14,200,000 gal./day
*San Felipe Springs	Del Rio	115 sec.-ft.	49,200,000 gal./day
*Good Enough Springs	Comstock	222 sec.-ft.	116,000,000 gal./day

Methods

Chemical and physical parameters were measured under field conditions at each site using a portable Hach Engineer's Laboratory DR-EL. The results are shown in Table 2 and are to be considered only as general indicators suggesting that these spring waters are slightly basic and hard in nature. These tests are in fair agreement with water tests conducted by other groups in the same general area. Most tests were run against known standards.

Collections of plant materials and rock scrapings were made (Table 7). Plankton and substratum samples were also taken. Each collection was examined for living diatoms and then divided. One-half of each sample was treated with formalin and saved as uncleaned material. The organic matter was removed from the remainder of the sample using 30% hydrogen peroxide and potassium dichromate. The resulting material was cleaned by decanting several times with distilled water and stored.

Each sample bottle was shaken and a dropper of material was obtained. This cleaned diatom material was placed on #0 cover slips and allowed to air dry. The cover slips were then placed on a hot plate and heated to 600°F for several hours. Each was inverted and placed on a standard microscope slide containing a drop of Hyrax. The entire mount was heated on a hot plate to 350°F for a short period of time to remove the mounting medium solvent.

A systematic search was made of each slide to identify and record each specimen (Table 6). Genus counts were tabulated to determine the relative abundance of each. These data are to be found in Tables 3 and 4.

Discussion

The three spring areas studied are similar in that they are of the artesian type, are formed by the Balcones zone of faulting and derive their water from the Edwards Aquifer. The close similarity of the chemical and physical parameters as shown in Table 2 bears this out. At this point the similarities end.

Barton Springs are found in and near a rather large slow moving stream. Aquarena Springs are dammed to form a large pond or lake-like environment. The Comal Springs studied produced a rapid flowing small stream in the area considered.

These environmental likenesses and differences are reflected in the diatom populations. Table 6 indicates that 18% of the diatom forms were observed in collections from all three spring areas, while 24% were found in, at least, two of the study sites. An analysis of the diatom population (Table 3) points up these similarities and differences even more.

A study of the structure of the diatom population (Table 4) reflects the water conditions. The diatom structure of Comal Springs is similar to that of a cool rapid stream containing a fair amount of plants. The increase in planktonic and bottom forms found in the other two spring areas are indicative of a more pond-like population structure. These results were expected and in agreement with the physical and chemical parameters observed (Table 2).

To carry this study one more step the author tabulated the number of forms recorded in each of the genera as found by other investigators studying springs (Table 5). This comparison is of value only in a very general way because of the great differences in the studies. One study is based on a years' collections, while another is developed from a single set of collections. The study by Foged (1951) considers six spring areas, but others have information on larger and smaller numbers. Some of the springs studied are of the seepage type which form bog-like conditions very dissimilar to the springs in this study.

The only real deviation in genus forms in this study from investigations by others appears to be Achnanthes and Gomphonema. The high percentage of the population and the variation of forms in the genus Achnanthes may be in part explained by the rocky environment and the water movement, which favors their development. As a general rule, diatoms of this genus tend to be bottom forms that live attached firmly to rocks and are able to compete successfully under these conditions.

The diatoms of the genus Gomphonema, on the other hand, are main epiphytic, found living on various higher plants. A rather diverse population of higher plant forms was observed and collected. This may account to some extent for the large number of Gomphonema forms recorded.

Many of the diatoms observed in this study have not been reported previously

TABLE 2. Chemical and physical parameters as found at the collecting sites.*

	#1	#2	#3	#4	#5
Alkalinity	290	280	278	256.5	320
Carbon Dioxide	3.8	4.6	4.2	----	4.2
Hardness, Total	227	260	280	280	260
Hardness, Ca.	176	195	221	----	200
Hardness, Mg.	51	65	59	----	60
Phosphate, Ortho	.11	.10	.60	----	.08
Nitrate	51.92	39.60	48.84	----	52.78
Nitrite	.021	.026	.027	----	.013
Sulfate	17.2	17.0	17.5	----	----
Manganese	----	.3	trace	----	----
Oxygen, Dissolved	6	6	5	7	9
pH	7.01	7.08	7.10	7.20	7.40
Turbidity	8JTU	13JTU	11JTU	----	8JTU
Water Temp.	21°C	22.5°C	21°C	21+°C	22.5°C
Air Temp.	29°C	25°C	24.8°C	26°C	30.1°C
Date	6/15/70	6/16/70	6/22/70	6/22/70	7/9/70
Time	6:30p.m.	9:45a.m.	9:00a.m.	10:00a.m.	9:00a.m.

#1 Travis Co.-Austin-Zilker Park-Barton Springs-west side near pool.
#2 Comal Co.-New Braunfels-Landa Park-Comal Springs
#3 Hays Co.-San Marcos-Aquarena Springs
#4 Hays Co.-San Marcos-Aquarena Springs-100' downstream from springs.
#5 Travis Co.-Austin-Zilker Park-Barton Springs-10' below spring area.

*All results in parts per million (ppm) unless otherwise noted.

as occurring in Texas. In fact, few published studies on recent diatoms have been done, although some fossil work on soil cores is available. Those diatoms listed in Table 6 that are followed by an asterisk have been reported from collections made from Texas. The other entities, to the author's knowledge, are new diatom records for the state.

TABLE 3. Analysis of diatom population by genera.

Genera	Comal Springs	Aquarena Springs	Barton Springs	Composite	Genera	Comal Springs	Aquarena Springs	Barton Springs	Composite
Achnanthes	15	12	13	19	Frustulia	--	1	2	2
Amphipleura	1	1	1	1	Gomphonema	11	11	9	22
Amphora	4	4	3	4	Gyrosigma	--	--	2	2
Bacillaria	1	--	--	1	Hantzschia	1	1	--	1
Caloneis	1	1	1	2	Meridion	--	--	1	1
Cocconeis	2	2	4	4	Navicula	11	12	17	29
Cymatopleura	--	--	2	2	Nitzschia	3	7	14	17
Cymbella	13	7	6	15	Pinnularia	--	1	3	4
Denticula	2	1	2	2	Rhopalodia	1	--	--	1
Diploneis	2	3	2	3	Stauroneis	2	1	4	4
Epithemia	--	1	--	1	Surirella	--	2	6	6
Eunotia	4	3	3	6	Synedra	4	8	3	10
Fragilaria	3	3	1	4	Terpsinoe	1	1	1	1

This study of three springs includes a total of 165 taxa representing 25 genera.

The diatom population as indicated by species ecological parameters is mainly that of a stable alkaline hard water environment. About 47% of all of the diatoms observed are considered to be alkaliphilous forms. When 5000 counts were conducted on each spring individually 50% of the diatoms in Barton Springs, 45% of those from Aquarena Springs and 46% from Comal Springs were alkaliphilous forms. In these same counts less than 3% could be considered acidophilous and along with this only about 15% of the total entities can be considered indicative of entrophic conditions.

Twenty-five per cent (44) of the total population are found typically in the Gulf Coast states. Twenty per cent of the observed diatoms are periphytes. Thirteen per cent were found to be rheophilous while only 16 forms are recognized as planktonic.

It should also be noted that diatoms considered to be aerophilic or soil diatoms were from time to time observed as isolated individuals. Diatoms that

TABLE 4. Structure of diatom population analyzed.*

Genera	Comal Springs		Aquarena Springs		Barton Springs	
	No. of Subord. Taxa	Appx. % of pop.	No. of Subord. Taxa	Appx. % of pop.	No. of Subord. Taxa	Appx. % of pop.
Achnanthes	15	41.03%	12	42.01%	13	35.33%
Amphora	4	9.96%	4	0.96%	3	3.34%
Caloneis	1	+	1	+	1	+
Cocconeis	2	12.30%	2	14.56%	4	19.08%
Cymbella	13	3.91%	7	0.80%	6	1.83%
Denticula	2	30.80%	1	15.68%	2	6.25%
Diploneis	2	0.24%	3	0.72%	1	0.35%
Eunotia	4	2.11%	3	0.91%	3	2.75%
Fragilaria	3	1.84%	3	3.20%	1	1.00%
Gomphonema	11	1.92%	11	10.80%	9	2.83%
Meridion	--	---	--	---	1	4.66%
Navicula	11	1.04%	12	2.15%	17	10.25%
Nitzschia	3	1.12%	7	4.96%	14	7.50%
Pinnularia	--	---	1	+	3	+
Stauroneis	2	+	1	+	4	+
Surirella	--	---	2	+	6	1.64%
Synedra	4	0.64%	8	2.96%	3	2.16%
Terpsinoe	1	0.80%	1	+	1	+

*Data based on 5000 counts.
+Present; low frequency.

TABLE 5. Number of taxa identified in each genus recorded from studies on springs.

	Foged (1951)	Whitford (1956)	Round (1957)	Round (1960)	Hohn (1961)	Reimer (1961)	Christensen (1970)
Achnanthes	11	2	11	12	17	8	19
Amphipleura	--	1	--	1	--	--	1
Amphora	6	3	4	2	5	2	5
Anomoeneis	3	--	1	1	--	1	--
Bacillaria	--	--	--	--	1	--	1
Biddulphia	--	2	--	--	1	--	--
Caloneis	12	--	2	6	6	5	2
Cocconeis	4	2	4	1	6	--	4
Campylodiscus	1	--	--	1	--	--	--
Cyclotella	3	1	1	--	2	--	--
Cymatopleura	2	--	2	2	--	--	2
Cymbella	21	1	5	12	6	14	15
Denticula	2	--	1	1	--	1	2
Diploneis	8	--	3	3	2	3	3
Epithemia	5	3	4	--	3	2	1
Eunotia	9	1	3	6	7	3	6
Fragilaria	13	1	7	9	10	2	4
Frustulia	2	--	--	2	1	--	2
Gomphonema	14	2	12	7	16	8	22
Gyrosigma	--	--	1	1	--	--	2
Hantzschia	2	--	1	1	1	--	1
Mastigloia	--	1	--	--	--	2	--
Melosira	9	3	2	1	4	--	--
Meridion	1	--	--	1	--	--	1
Navicula	80	2	18	26	60	33	29
Neidium	2	--	4	3	2	6	--
Nitzschia	20	6	11	12	15	18	17
Opephora	1	--	--	--	1	--	--
Pinnularia	20	--	7	5	3	6	4
Pleurosigma	--	2	--	--	--	--	--
Rhoicosphenia	--	--	1	--	--	--	--
Rhopalodia	3	--	--	1	1	4	1
Stauroneis	8	1	3	5	2	7	4
Stephanodiscus	2	1	--	--	--	--	--
Surirella	9	1	5	8	1	5	6
Synedra	12	4	5	4	12	4	10
Tabellaria	3	--	1	--	--	--	--
Terpsinoe	--	1	--	--	1	--	1
Thalassiosire	--	--	--	--	1	--	--

fit into this category include Achnanthes linearis, Achnanthes hustedtii, Amphora ovalis var. pediculus, Eunota pectinalis var. minor, Hantzschia amphioxys, Navicula confervacea, Navicula mutica and Nitzschia kulzingiana. Their presence may be the result of the heavy rains and flooding of the areas a few weeks before the collections were made.

The following taxa are by the author considered to be organic pollution indicators when observed in large numbers in the diatom population: Amphipleura pellucida, Cymatopleura solea, Fragilaria capicina var. mesolepta, Gomphonema angustatum and varieties, Gomphonema intricatum, Gomphonema olivaceum, Meridion circulara, Navicula accomoda, Navicula cryptocephala and varieties, Navicula cuspidata, Navicula lanceolata, Navicula pupula, Navicula rhynchocephala, Nitzschia amphibia, Nitzschia frustulum var. subsalina, Nitzschia kulzingiana, Nitzschia linearis, Nitzschia palea and varieties, Nitzchia sigmoidea, Rhopalodia gibberula var. protracta, Stauroneis anceps, Stauroneis phoenicunteron f. gracilis, Synedra acus and Synedra ulna.

This group of diatoms represents 18.4% of the taxa and 23.4% of the population of Barton Springs indicating a high pollution stress condition. The Aquarena Springs assemblage of these indicator diatoms was 14.5% of the taxa and 15% of the diatom population suggesting only minor but chronic pollution present. Comal Springs with about 13% of the taxa and only 6% of the population being from this group of diatoms is the lowest the author has ever observed and shows a normal, noneffected spring.

The use of these three parameters: indicator species, diversity and population structure of diatoms when following standard procedures, can present a clear and accurate picture of the long term organic pollution conditions of flowing bodies of water.

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TABLE 6. Identified diatoms from three major springs: (1) Barton Springs, (2) Aquarena Springs and (3) Comal Springs.

	(1) Barton Springs	(2) Aquarena Springs	(3) Comal Springs
<u>Achnanthes</u>			
A. affinis Grun.	+	+	+
A. exilis Kutz.	-	-	+
A. exigua Grun.*	+	+	+
A. exigua var. constricta (Grun.) Hust.	-	+	+
A. exigua var. heterovalva Krasske*	-	-	+
A. flexella (Kutz.) Brun.	+	-	-
A. hauchiana Grun.	+	+	-
A. hungarica (Grun.) Grun.*	-	-	+
A. hustedtii (Krasske) Reim.	+	-	-
A. inflata (Kutz.) Grun.*	-	+	+
A. lanceolata (Breb.) Grun.*	+	+	+
A. lanceolata var. dubia Grun.*	+	+	+
A. lanceolata var.?	-	+	-
A. linearis (W.Sm.) Grun.	+	+	+
A. linearis f. curta H. L. Sm.	+	+	+
A. marginulata Grun.	+	-	+
A. microcephala (Kutz.) Grun.*	+	+	+
A. minutissima Kutz.	+	+	+
A. wellsiae Reim.*	+	-	+
<u>Amphipleura</u>			
A. pellucida Kutz.	+	+	+
<u>Amphora</u>			
A. normani Rabh.	+	+	+
A. ovalis Kutz.	+	+	+
A. ovalis var. pediculus Kutz.	+	+	+
A. perpusilla Grun?	-	-	+
A. veneta Kutz.	-	+	-
<u>Bacillaria</u>			
B. paradoxa var. tumidula Grun.	-	-	+
<u>Caloneis</u>			
C. bacillum (Grun.) Cl.*	+	+	+
C. ventricosa var. truncatula (Grun.) Meist.*	-	-	+

TABLE 6. Continued.

	(1)	(2)	(3)
Cocconeis			
C. pediculus Ehr.*	+	-	-
C. placentula Ehr.*	+	+	+
C. placentula var. euglypta*	+	-	-
C. placentula var. lineata (Ehr.) V. H.*	+	+	+
Cymatopleura			
C. elliptica (Breb.) W. Sm.	+	-	-
C. solea (Breb.) W. Sm.	+	-	-
Cymbella			
C. affinis Kutz.	+	-	+
C. amphicephala Naegeli	-	-	+
C. aspera (Ehr.) Cl.	+	+	+
C. cistula (Hemp.) Grun.	+	+	-
C. hustedtii Krasske	-	+	-
C. laevis Naegeli	+	-	+
C. microcephala Grun.	-	+	+
C. naviculiformis Auerswald	-	+	+
C. pusilla Grun.	-	-	+
C. similis Krasske	-	-	+
C. tumidula Grun.	-	-	+
C. ventricosa Kutz.	+	+	+
C. sp. #1	+	+	+
C. sp. #2	-	+	+
C. sp. #3	-	-	+
Denticula			
D. elegans Kutz.	+	+	+
D. tenuis Kutz.	+	-	+
Diploneis			
D. elliptica (Kutz.) Cl.*	-	+	-
D. oblongella (Naeg. ex Kutz.) Ross*	-	+	+
D. puella (Schum.) Cl.*	+	+	+
Epithemia			
E. zebra var. saxonica (Kutz.) Grun.	-	+	-
Eunotia			
E. arcus var.?	-	-	+
E. curvata (Kutz.) Lagerst.*	+	+	-
E. maior (W. Sm.) Rabh.*	-	+	+
E. maior var. ventricosa A. Cl.	-	-	+
E. monodon Ehr.*	-	+	+
E. pectinalis var. minor (Kutz.) Rabh.*	+	-	-

TABLE 6. Continued.	(1)	(2)	(3)
Fragilaria			
F. capucina var. mesolepta Rabh.	-	-	+
F. construens (Ehr.) Grun.*	-	+	+
F. crotonensis Kitton*	-	+	+
F. virescens Ralfs	+	+	-
Frustulia			
F. rhomboides var. amphipleuroides (Grun.)	+	+	-
F. rhomboides var. viridula (Breb.) Cl.	+	-	-
Gomphonema			
G. abbrevialum Kutz.	+	-	+
G. abbrevialum var. brasiliense Grun.	-	-	+
G. acuminatum Ehr.	+	-	-
G. affine Kutz.	-	+	-
G. angustatum (Kutz.) Rabh.	+	+	+
G. angustatum var. intermedia Grun.	-	+	-
G. angustatum var. producta Grun.	-	+	-
G. apicatum Ehr.	+	-	-
G. gracile Ehr.	-	+	-
G. gracile var. naviculoides (W. Sm.) Grun.	-	-	+
G. intricatum Kutz.	-	-	+
G. intricatum var. dichotoma Grun.	-	+	-
G. lagenula Kutz.	-	-	+
G. lanceolatum Kutz.	+	-	+
G. lanceolatum var. insignis (Gregory) Cl.	-	-	+
G. longiceps var. gracilis Hust.	-	+	+
G. longiceps var. subclavata Grun.	+	-	-
G. olivaceum Rhr.	+	-	-
G. parvulum (Kutz.) Grun.	+	+	+
G. parvulum var.?	-	+	-
G. sphaerophorum Ehr.	+	+	+
G. sp #1	-	+	-
Gyrosigma			
G. attenuatum (Kutz.) Rabh.*	+	-	-
G. obscurum (W. Sm.) Griff. & Henfr.	+	-	-
Hantzschia			
H. amphioxys (Ehr.) Grun.	-	+	+
Meridion			
M. circulara (Grev.) Ag.	+	-	-

TABLE 6. Continued.

	(1)	(2)	(3)
Navicula			
N. accomoda Hust.*	-	-	+
N. confervacea Kutz.*	-	+	-
N. cryptocephala var.?	+	-	-
N. cuspidata (Kutz.) Kutz.*	+	-	-
N. exigua var. capitata Patr.	-	-	+
N. festiva Krasske	-	+	+
N. graciloides A. Mayer	-	+	-
N. grimmei Krasske*	+	-	-
N. gysingensis Foged	-	+	-
N. halophila (Grun.) Cl.*	-	-	+
N. heuferia Grun.*	+	-	-
N. hustedii Krasske*	-	+	-
N. lanceolata (Ag.) Kutz.	+	-	-
N. luzonensis Hust.*	+	-	-
N. minuscula Grun.	+	+	-
N. mutica Kutz.*	+	+	+
N. notha Wallace*	+	-	-
N. odiosa Wallace	+	-	+
N. pupula Kutz.*	+	-	+
N. pupula var. capitata Skv. Meyer*	+	-	-
N. pupula var. mutata (Krasske) Hust.	-	+	-
N. pupula var. rectangularis (Greg.) Grun.	-	+	-
N. radiosa Kutz*	+	+	+
N. radiosa var. parva Wallace*	-	-	+
N. radiosa var. tenella (Breb. ex Kutz.) Grun.*	+	+	+
N. rhynochocephala Kutz.*	+	-	-
N. sanctaecrucis Ostr.	+	-	-
N. secreta var. apiculata Patr.*	+	-	-
N. seminulum Grun.	-	-	+
Nitzschia			
N. amphibia	+	+	+
N. apiculata	+	-	-
N. clausii Hantzsch	+	-	-
N. debilis (Arn.) V. H.	+	-	-
N. frustulum var. subsalina Hust.	+	-	-
N. gracilis Hantzsch	-	+	-
N. hantzschiana Rabh.	-	+	+
N. heufferiana Grun.	+	-	-
N. kulzingiana Hilse	+	+	-
N. lacunarum Hust.	+	-	-
N. linearis W. Sm.	+	-	-
N. palea (Lutz.) W. Sm.	+	+	+
N. palea var.?	+	-	-
N. parvula Levis	+	-	-
N. sigmoidea (Ehr.) W. Sm.	-	+	-
N. spectabilis (Ehr.) Ralfs	+	-	-
N. tryblionella var.?	+	+	-

TABLE 6. Continued.

	(1)	(2)	(3)
<u>Pinnularia</u>			
P. intermedia (Lagerst.) Cl.	-	+	-
P. streptoraphe Cl.	+	-	-
P. stomatophora (Grun.) Cl.	+	-	-
P. subcapitata Greg.	+	-	-
<u>Rhopalodia</u>			
R. gibberula var. protracta Grun.	-	-	+
<u>Stauroneis</u>			
S. anceps Ehr.*	+	-	+
S. kriegeri Patr.	+	-	-
S. phoenicunteron f. gracilis (Ehr.) Hust.*	+	-	-
S. smithii Grun.	+	+	-
<u>Surirella</u>			
S. angustata Kutz.	+	+	-
S. linearis W. Sm.	+	-	-
S. linearis var. constricta (Ehr.) Grun.	+	-	-
S. linearis var. helvetica (Brun.) Meister	+	+	-
S. ovata Kutz.	+	+	-
S. robusta?	+	-	-
<u>Synedra</u>			
S. acus Kutz.*	-	-	+
S. amphicephala Kutz.	-	+	-
S. amphicephala var. austriaca (Grun.) Hust.	-	+	-
S. goulardi (Breb.)	+	-	-
S. rumpens var. fragilarioides Grun.	-	+	-
S. rumpens var. scotica Grun.	-	-	+
S. ulna (Nitz.) Ehr.*	-	+	+
S. ulna var. amphirhynchus (Ehr.) Grun.	+	+	+
S. ulna var. danica (Kutz.) V. H.*	+	+	-
S. ulna var. oxyrhynchus?	-	+	-
<u>Terpsinoe</u>			
T. musica Ehr.	+	+	+

TABLE 7. Collection Samples

SPRING AREA	SAMPLE NUMBER	ORIGIN OF SAMPLE
Barton Springs	105	bottom sample plus plant materials
	106	rock scrapings in seep
	107	angiosperm plant material
	108	rock scrapings
	119	algae (filmentious)
	120	bottom sample
	121	angiosperm
Comal Springs	109	angiosperm material
	110	rock scrapings
	111	rock scrapings plus bottom material
Aquarena Springs	112	rock scrapings
	113	angiosperm material
	114	rock scrapings
	115	rock scrapings
	116	angiosperm material
	117	scrapings, wooden pilings
	118	plant material - sagitaria

BIBLIOGRAPHY

________________ 1968. The Texas Water Plan. Texas Water Development Board. Austin, Texas. pp. 11-5 to 11-8.

Cholnoky, B.V. 1933-34. Analytisehe Benthes-Untersuchugen, III Die Diatomeen einer Kleinen Quelle in der Nahe der Stadt Vac. Arch. Hydrobiol. 26:207-312.

Christensen, C.L. 1969. Notes on Iowa Diatoms IX: Variation in the Genus Eunotia. Proc. Iowa Acad. Sci. 76:62-68.

Cleve-Euler, A. 1951-55 Die Diatomeen von Schweden und Finnland. Kongliga Svenska Vetenskaps-Akademiens Handlinger, Fjarde Serien.

Foged, N. (1951). The Diatom Flora of Some Danish Springs. Part I. Strandkaer. The Mols-laboratory Nat. Jutlandica 4:1-84.

Hill, R.T. and Vaughn, T.W. (1898) Geology of the Edwards Plateau and Rio Grande Plain adjacent to Austin and San Antonio, Texas, with special reference to the Occurrence of Underground Waters. U.S. Geol. Survey Eighteenth Annual Report., Pt. 2, pp. 279-312.

Hohn, M.H. 1959. The use of diatom populations as a measure of water quality in selected areas of Galveston and Chocolate Bay, Texas. Pub. of the Institute of Marine Science 6:206-212.

Hohn, M.H. 1961. The relationship between species diversity and population diversity in diatom populations from Silver Springs, Florida. Trans. Amer. Micros. Sox. 80:140-165.

Hustedt, F. 1930. Bacillariophyta. In A. Pascher's Die Susswasser-Flora Mitteleuropas. Vol. 10:pp. 1-466. Jena.

Hustedt, F. 1945. Diatomeen aus Seen und Quellgebieten der Balham Halbinsel Arch. Hydrobiol. 40:876-973.

Meinzer, O.E. (1927) Large Springs in the United States. U.S.G.S. Water-Supply Paper 557, pp. 27-41.

Patrick, R. 1946. Diatoms from Patschke Bog, Texas. Not. Nat. 170:1-7.

Patrick R. and Reimer, C.W. 1966. The Diatoms of the United States. Acad. Nat. Science Phil. Monograph No. 13, pp. 99-672.

Reimer, C.W. 1961. Some aspects of the Diatom Flora of Cabin Creek Raised Bog, Randolph Co., Indiana. The Proc. of the Ind. Acad. of Sci. Vol. 71:305-319.

Round, F.E. (1957). A Note on Some Diatom Communities in Calcareous Springs and Streams. Linn. Soc. (Bob.) LV, pp. 662-668.

Round, F.E. (1960). A Note on the diatom Flora of some springs in Malham Torn area of Yorkshire. Archiv. fur Protistenhunde. 104 Band, Heft 4, pp. 515-526.

Sellards, E.H., W.S. Adkins and F.B. Plummer, 1966. Stratigraphy, The Geology of Texas, Vol. 1, The Univ. of Texas Bulletin, N3232, Aug. 22, 1932. 5th printing. pp. 137-268.

Van Heurck, H.F. 1880-1885. Synopsis des Diatomees de Belgique. Anvers L'auteur. 132 plates.

Watkins, Gustav McKee (1930). Vegetation of San Marcos Springs. Unpublished Thesis. Univ. of Texas.

Whitford, L.A. 1956. Algae in the springs and spring streams in Florida. Ecology vol. 37, no. 3:433-442.

Yount, J.L. 1956. Factors that control species numbers in Silver Springs, Florida. Limnol. and Oceanogr. 1(4):286-295.